Reducing Vehicle Auxiliary Loads Using Advanced Thermal Insulation and Window Technologies

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Overview

- Introduction
- Thermal Interactions
- Strategies for Increased Energy Efficiency and Passenger Comfort
- Insulation and Window Technologies
- Retrofit of a Midsize Sedan
- Outdoor Testing
- Design and Modeling
- Summary

Introduction

Auxiliary Loads for Cooling

and Heating Cause:

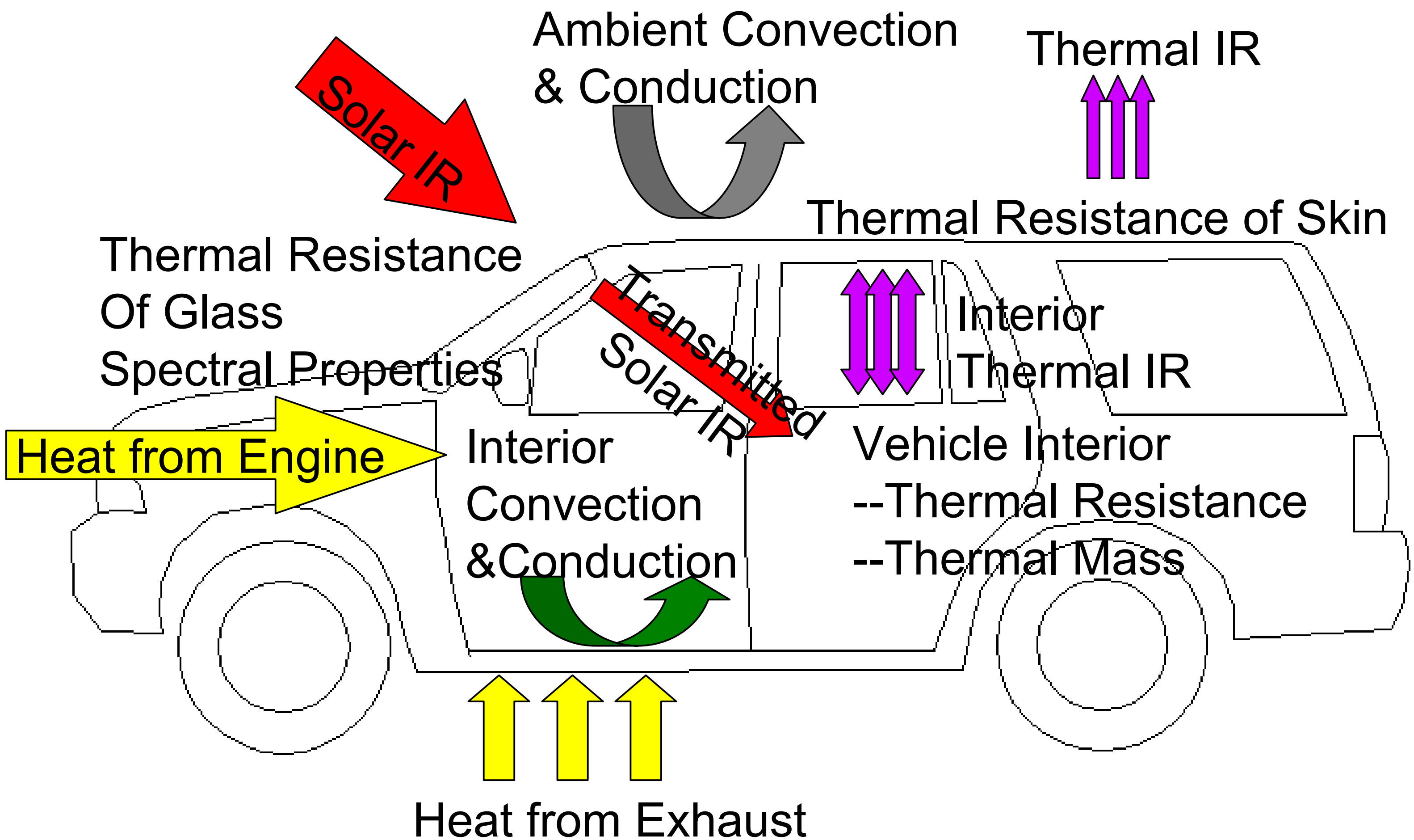
- Fuel penalties for conventional and hybrid cars
- Reduced range in electric vehicles

Introduction

Thermal Management of Passenger Compartment :

- Reduction in emissions
- Reduced degradation of interior surfaces
- Increased driver and passenger comfort
- Improved safety

Thermal Interactions



Energy Efficiency & Comfort

- Reduction of HVAC loads
  - Reduction of transmitted solar IR
    - Spectrally selective glazing
    - Smaller overall glass area
  - Reduction of conductive & convective losses
    - Thermal insulation of passenger compartment
  - Reduction of interior thermal mass
    - Use of low thermal mass materials
    - Decoupling with insulation

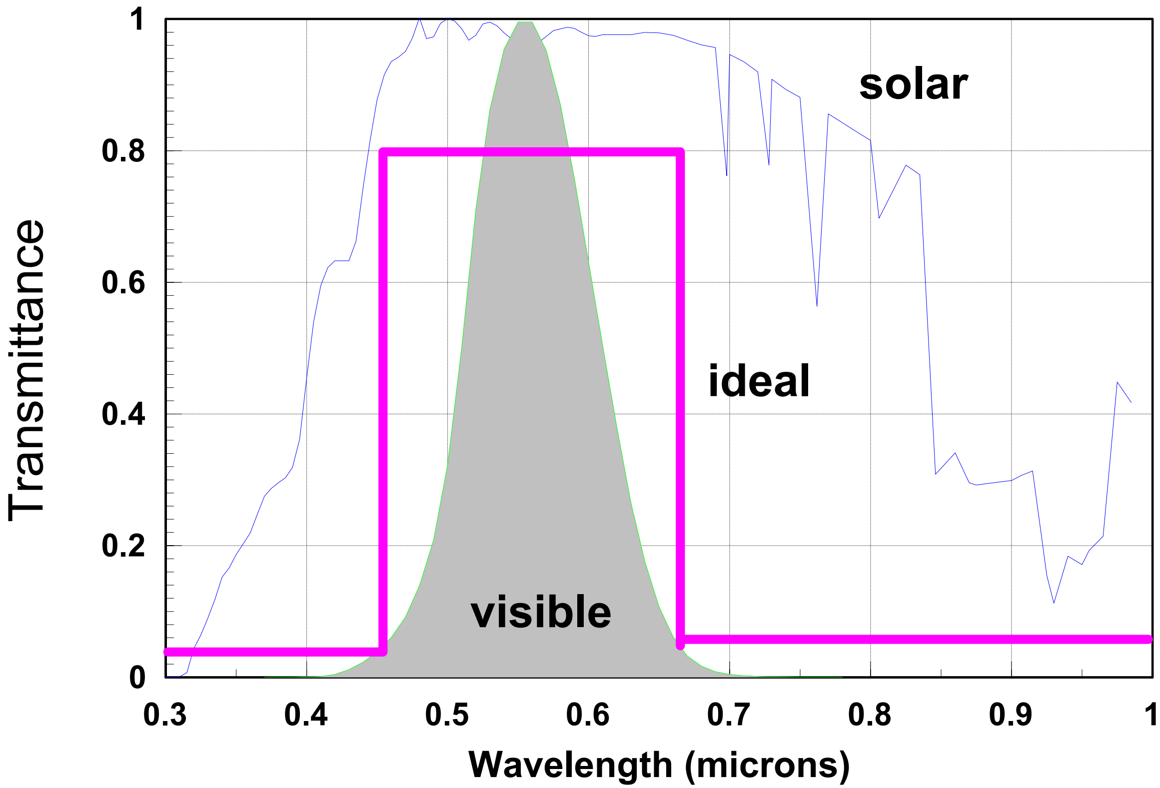
Window Technology

Reduction of Transmitted Solar IR to Lower Cooling Load

- Spectrally selective coatings
  - Reflection of solar infrared
  - Laminated or double pane glazing
- Tinted glass
  - Absorption of visible and solar infrared
- Electrochromic films

Window Technology

Ideal Performance of Spectrally Selective Coating



Window Technology

Reduction of Thermal Conduction,

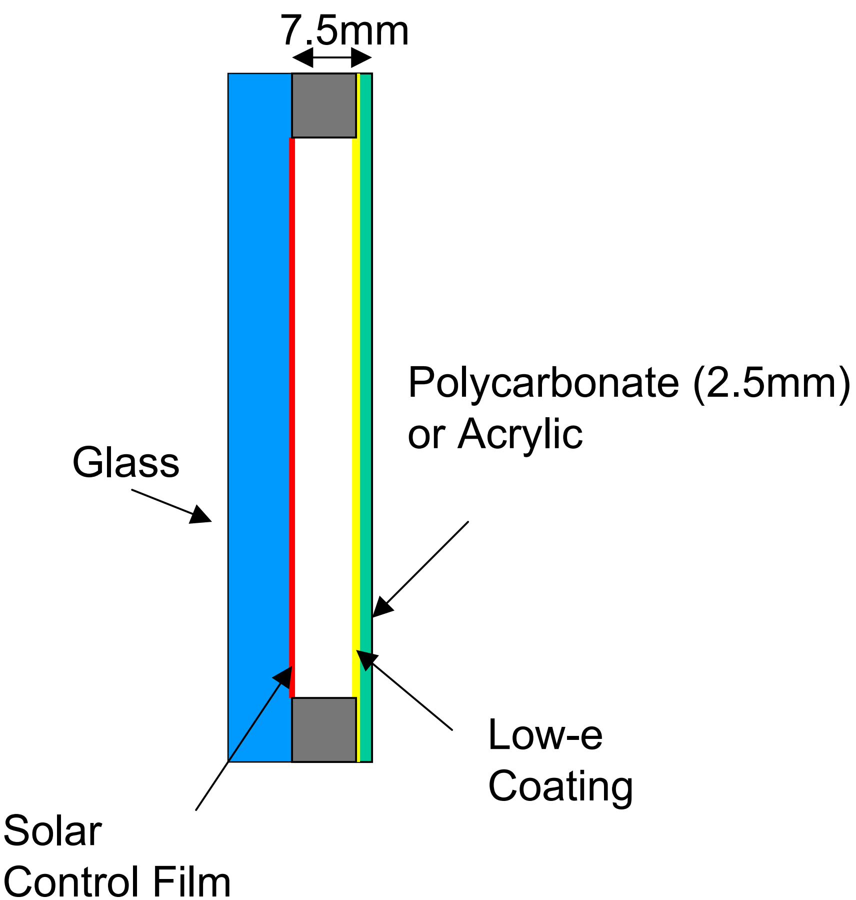
Convection and Infrared

- Double pane glazing units
  - Sealed or adjustable pressure
  - Optical coating is protected
- Vacuum glazing
  - Hard vacuum
  - Pillars required to separate panes

Window Technology

Window Technology

- IG unit
  - double pane on side and rear lights
  - spectrally selective solar control films
  - warm edge spacers
  - air filled



Window Technology

Demonstration Double Pane Glazing

Detail of Front Side Light

Back Light Ready for Installation

Insulation Technology

- Insulating Foam
  - In-place foaming
  - Preformed pieces
  - λ as low as 0.02 W/mK
- Gas Filled Panels
  - Integrated into interior trim
  - λ adjustable as little as 0.0074 W/mK

Insulation Technology

Advanced Thermal Insulation

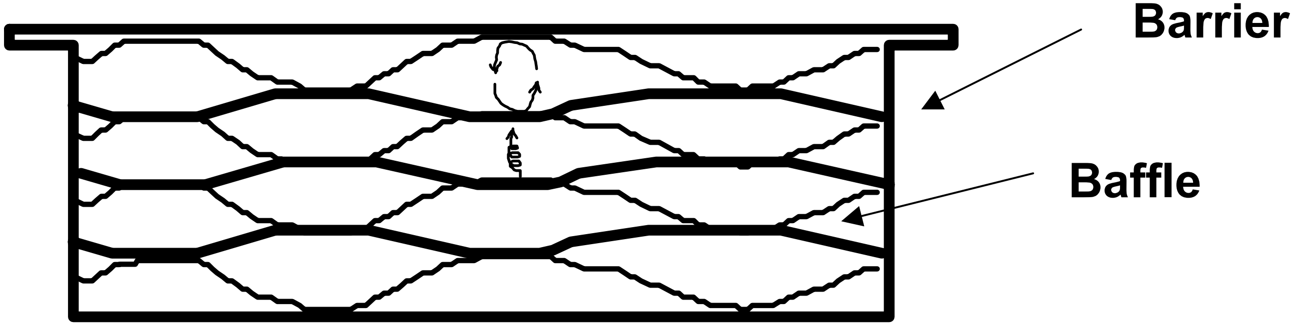
Gas Filled Panels

- Thermal Insulation *System*
- Panel device of thin sheet materials
- Multilayer reflective baffles suppress radiation and convection
- Hermetic barrier envelope retains low conductivity gas fill at atmospheric pressure

Insulation Technology

GFP Components

Low conductivity gas fill
Hermetic barrier enclosure
Reflective baffle



Insulation Technology

GFP Gases

Air
Argon
Krypton
Xenon
Chemical Replacements for CFCs

Inert noble gases from air have low conductivity and no environmental problems

Insulation Technology

GFP Barrier

Multilayer polymer barrier films
Heat sealed hermetic enclosure
Excellent air and water barrier

Barrier component retains low conductivity gas and blocks air ingress

Insulation Technology

GFP Test Results

Gas type (N panels)	Mean Temperature (°C)	Conductivity (W/m·K)	R-Value/inch (hr·ft·°F/ Btu·in)
Xenon (5)	23.9	0.0074	19.5
Krypton (11)	23.9	0.0116	12.5
Argon (3)	23.9	0.0199	7.2
Air (3)	23.9	0.0281	5.1

ASTM C-518 Procedure, Heat flow meter apparatus
Measurements conducted independently by Oak Ridge National Laboratory

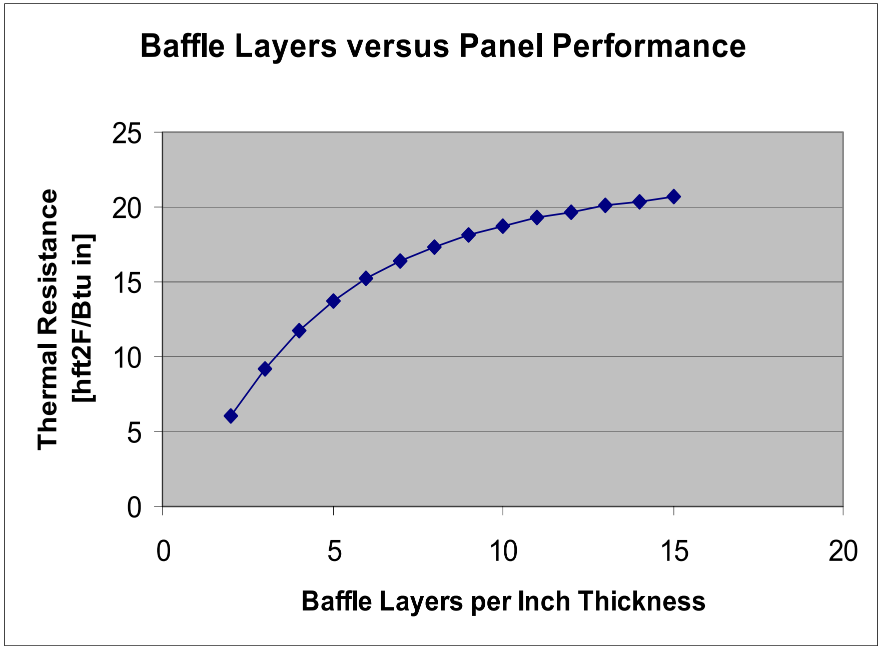
Insulation Technology

GFP General Characteristics

Versatile geometry allows filling available volume
Typical densities 0.5 -1.5 pcf
Flexibile, anisotropic stiffness
Collapsible for shipping and handling
Clean
Air and Water Proof

Insulation Technology

- Fill Gas Xenon
- 11 Layers per inch
- Thermal Resistance R=19.5 [hft2F/Btu in]



Retrofit of a Sedan

Stock Door Panel

Insulated Door Panel

Thermal Resistance R~25 [hft2F/Btu]

Weight Increase ~ 120 gr

Retrofit of a Sedan

- Proof-of-concept for automotive applications
- Investigate thermal performance of stock door
- Investigate heat flow paths and thermal bridges
- Before and after -- car door

Testing -- Car door mounting

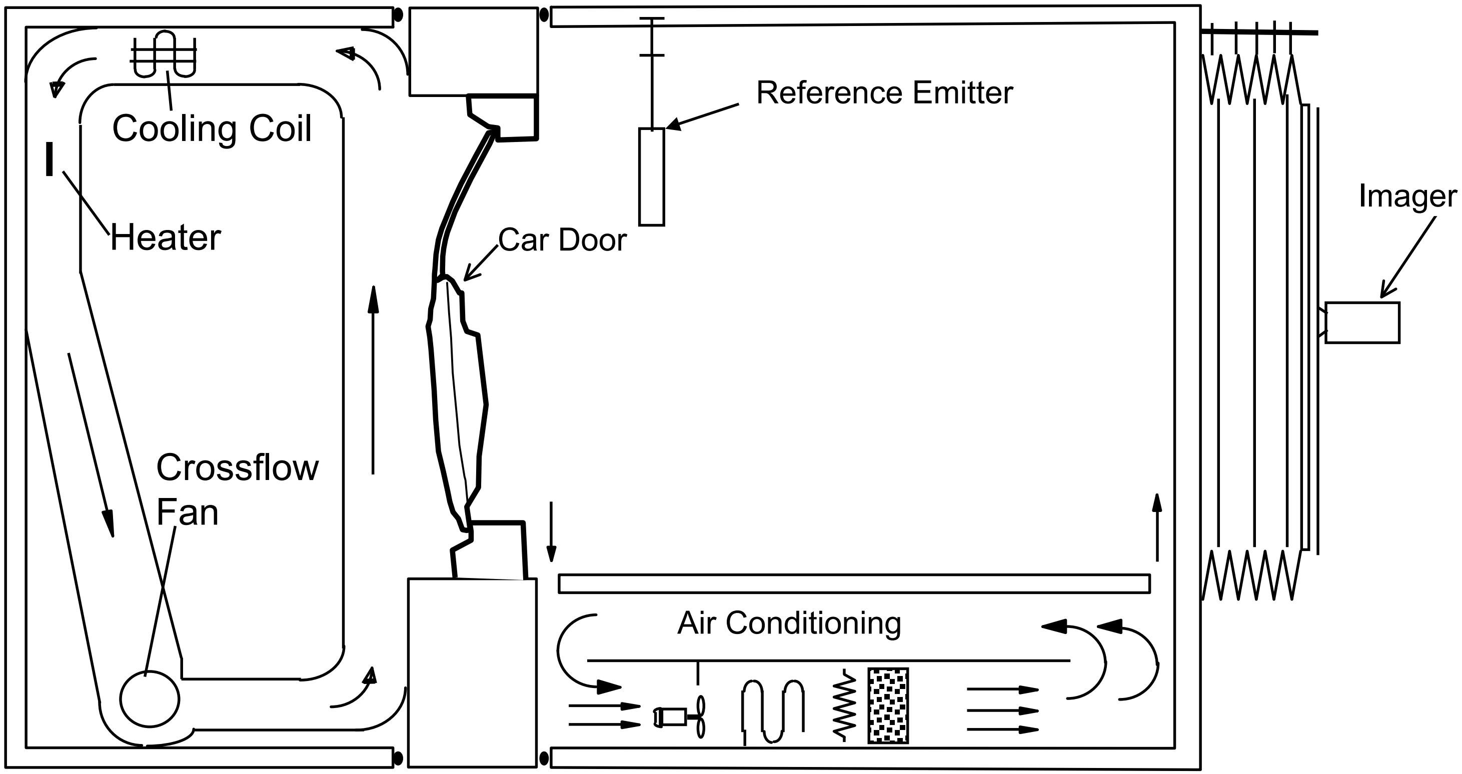
Testing -- Steady State Heating

Climate Chamber

32°F, 0°C

Measurement Chamber

77°F, 25°C



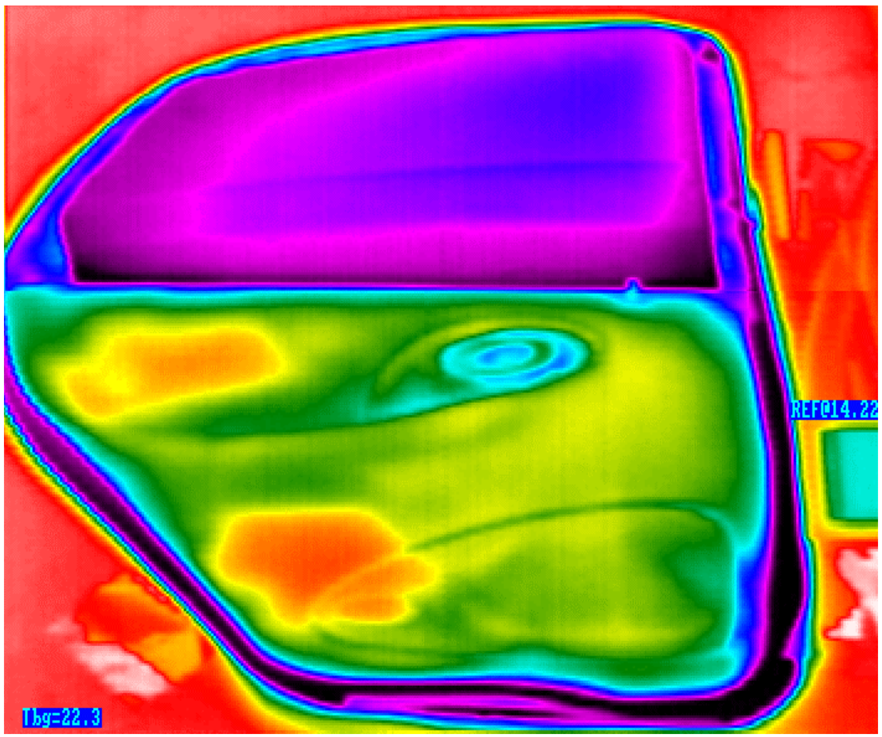
(not to scale)

Testing --Infrared Thermography

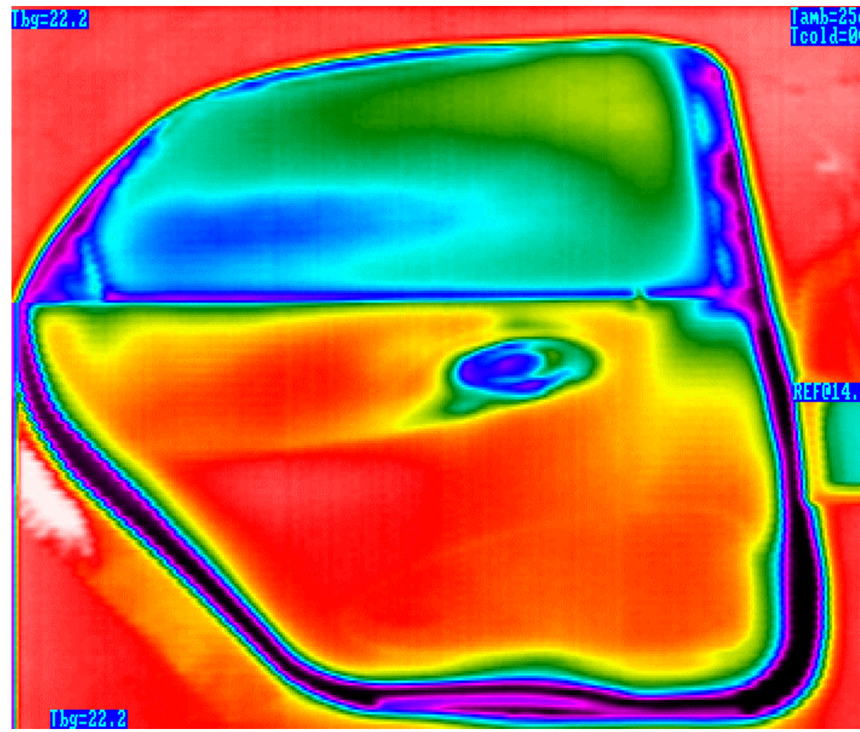
Testing -- Before and After

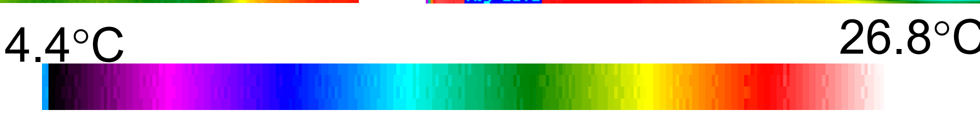
Infrared thermal images, warmer temperatures indicate better insulation

Stock Door



Door w/ GFP Insulation



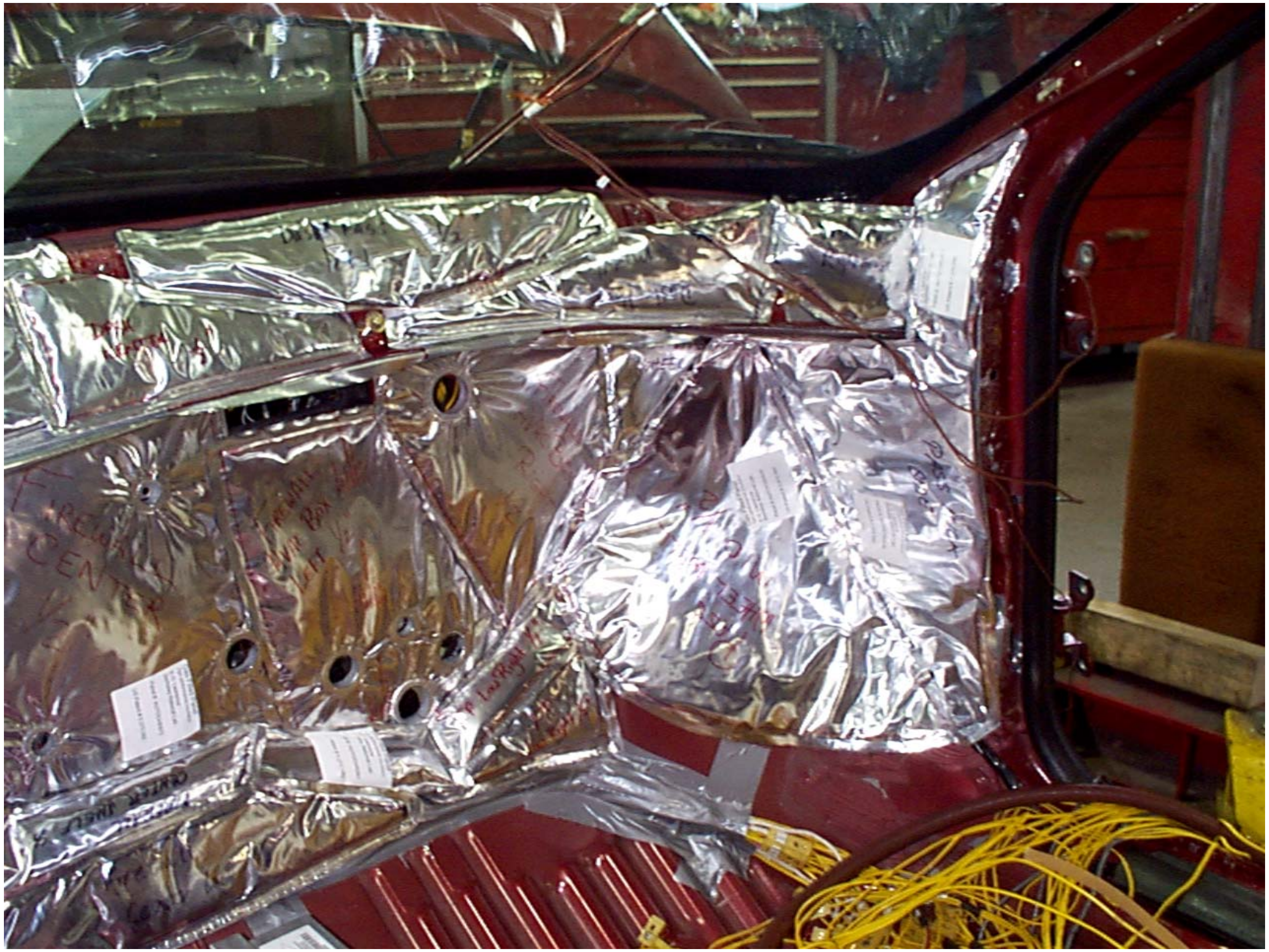


Thermal Testing

Results

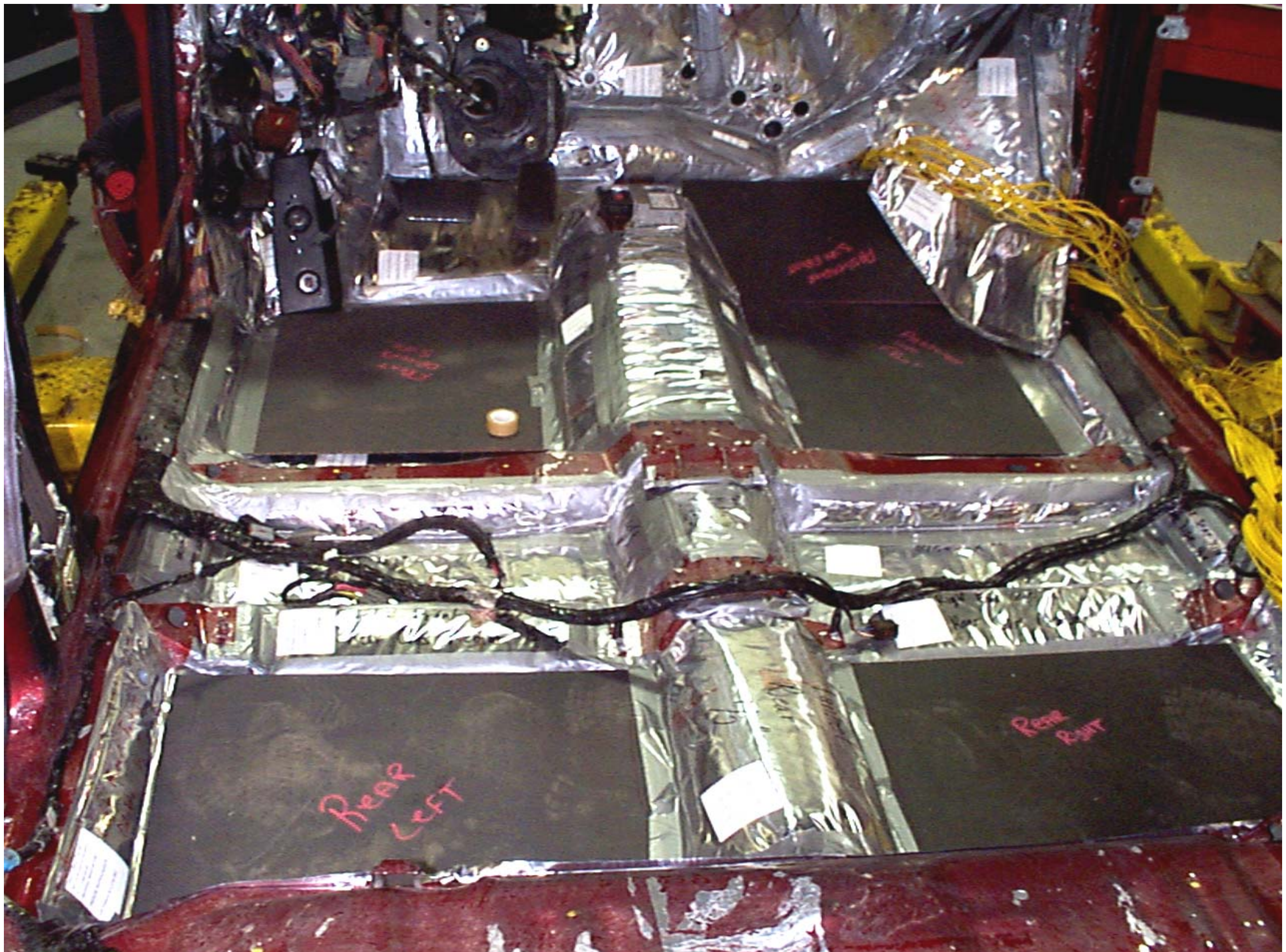
Results	**Maximum Temperature**	**Minimum Temperature**	**Average Temperature**	**Reduction of Heatflow**
Stock Door Trimpanel	22.4	3.3	17.5	
Stock Glass	13.6	3.6	7.4	
GFP Door Trimpanel	24.0	6.7	20.9	**60%**
Double Pane Glass	19.2	7.3	15.0	**48%**

Installation -- Dashpanel



Installation -- Headliner

Installation -- Floorpan



Testing PNGV Car

- Hot wind tunnel test under driving condition, 48kph, 64kph and 96kph
  - interior temperature after soaking ~ 55°C
- Cold wind tunnel test under driving condition, 48kph, 64kph and 96kph
  - interior temperature after soaking ~ -18°C

Results PNGV Car

- GFP Insulation performed as designed
- Weight savings accomplished with GFP technology made the use of double pane windows possible
- 75% reduction of cooling load
- 80% reduction of heating load

Outdoor Testing

- Requires test and baseline vehicle
- Fairly inexpensive
- Poor repeatability
- Vehicle Simulation can “normalize” data between test days

Outdoor Testing -- Sensors

Most Common Errors

- Heatflux sensor mounted in direct contact on vehicle skin
- Temperature probe mounted on reinforcement structure
- Solar radiation sensor mounted behind glass

Outdoor Testing -- Sensors

Good Practice

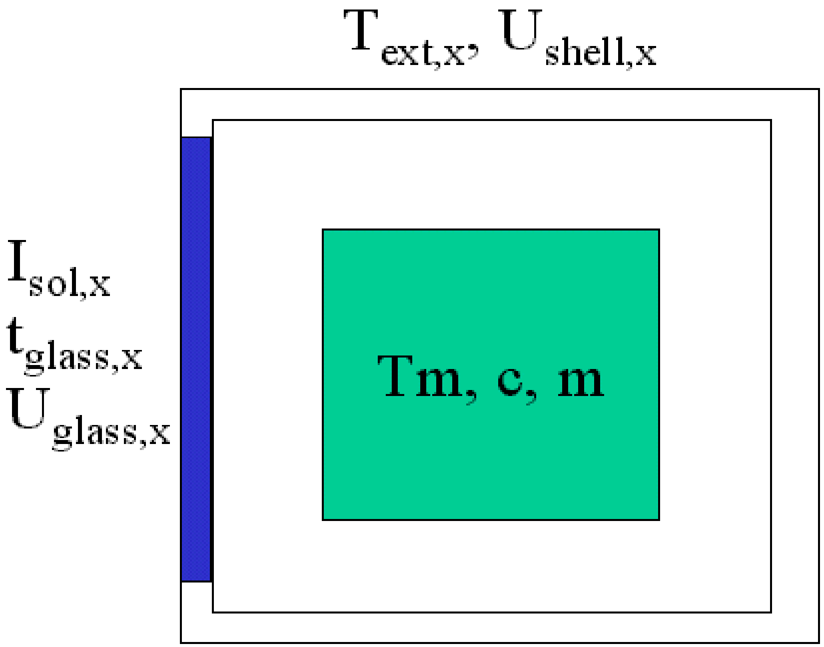
- Temperature probes mounted in the direction of the heat flow
- Temperature probes electrically isolated
- Solar radiation sensors mounted on each glass surface orientation
- Heatflux sensors mounted in solid thermal contact on both sides

Design and Modeling

- Equation based vehicle modeling
  - Accommodates design optimization
  - Automatically includes all relevant parameters
  - Easily transfers across vehicle platforms
  - Allows parametric studies

Simulations

- Simulation based on outdoor testing
  - Input for simulation parameters
  - Model validation
  - Normalizing test data

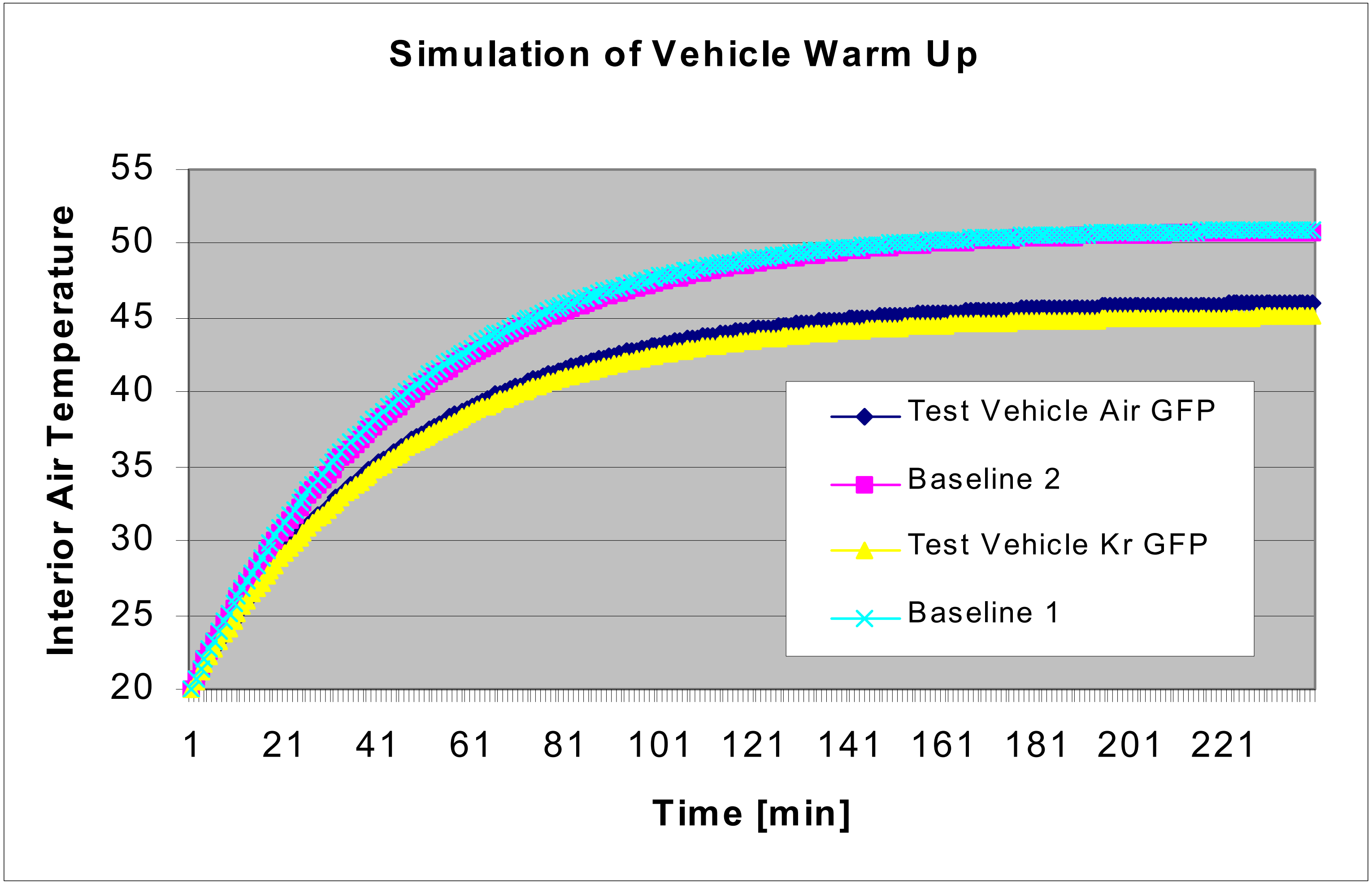


Simulation

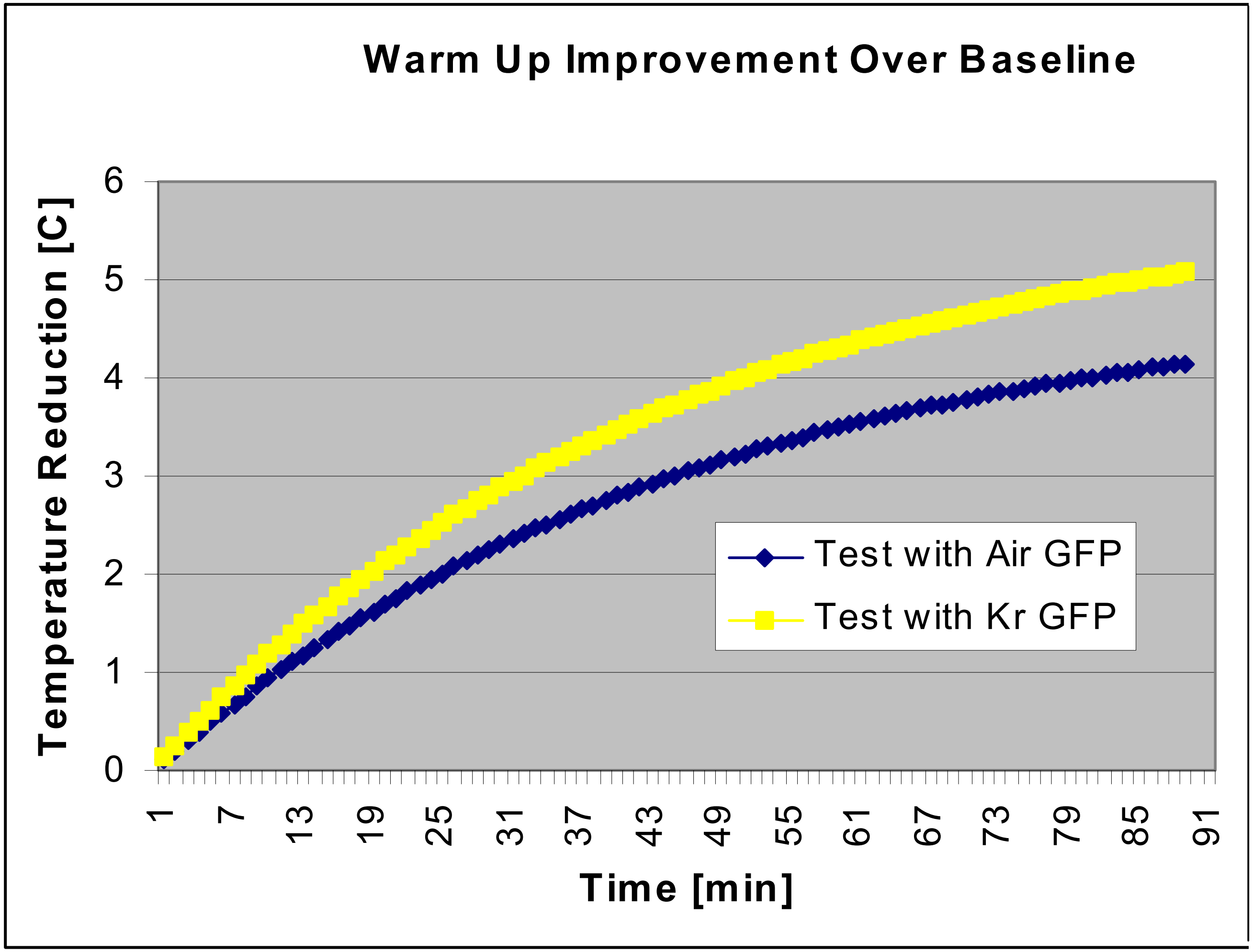
Objective:

- Evaluation of headliner insulation and spectrally selective glazing to lower interior temperatures under soaking conditions

Simulation Results



Simulation Results



Conclusions

- Thermal loads can be substantially reduced without loss of comfort or vehicle performance
- Technology adaptable from building industry
- Thermal management allows downsizing of HVAC equipment
- Increased fuel economy
- Enabling technology for alternative drivetrain vehicles
- Improved marketability

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